

Appendix A

Process Description for Waste Receiving and Preparation

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000



Appendix A

Process Description for Waste Receiving and Preparation

All retrieved waste is delivered to the Sorting Deck zone area of the treatment facility. The retrieved waste may be delivered in as retrieved bulk and unit forms via front-end loaders or, it may be delivered in special re-usable transport boxes. These boxes are nominally 5 ft x 5 ft x 10 ft long and are delivered by AGVs or other mobile or fixed unit material handling equipment. The waste products are dumped into four containers equipped with walking floor conveyors. Each of these containers has a net capacity of about 5-6 m³. These containers provide the 24-hour operational surge capacity for the downstream treatment processes.

The Sorting Deck has an approximate overall surface configuration that is 25 ft long x 75 ft wide. The top of the deck is 15 ft above the base floor of the facility. The deck is sized to allow between 10 to 20 m³ of retrieved waste materials to be deposited on it at one time for initial sorting, group classification, and direction to processing operations. The large variation in volume is due to the inconsistent forms in which wastes will be retrieved. At any time the retrieved waste will be comprised of any or all of the following forms: loose soils, loose debris, drummed wastes, boxed wastes, bundled wastes, and unit item wastes. The entire deck area is enclosed as a Zone III radiological area. All operations within this zone are accomplished utilizing remote controlled equipment. Access in and out of this area is via controlled isolation airlocks. The surface of the deck is configured into three work areas. Each of the areas is equipped with two 12 ft wide x 20 ft long parallel walking floor type conveyors. As material is fed onto the receiving end of the deck, the walking floor conveyors advance it from the back to the front edge of the conveyor(s) effectively spreading out the received wastes in a controlled depth pattern over the entire deck section area. The wastes are now ready for sorting and distribution to the different unit operations in the characterization processing area.

Operators located in an elevated and isolated control room utilize three hydraulic material handling booms and an overhead bridge crane to spread, sort, classify and direct the various waste products to the mechanical unit process cells of the characterization area. The control room is a Zone I radiological area. It overlooks the entire length of the Sorting Deck from one side and provides viewing into the other areas of the characterizations zones from its opposite side. In addition to direct viewing of the work areas, the operators also utilize remote-mounted video cameras to provide 100% coverage and close-up viewing capability for both operations and recording. Areas where waste materials are handled and processed are equipped with Beta-Gamma detectors that allow the operators to isolate hot waste items that require special handling and do not fall within the acceptable criteria for treatment.

The portion of the retrieved waste that is sorted needs to be moved perpendicular to the walking floor to the designated mechanical process cells that prepare the different waste forms for sampling, assay, and detailed characterization. Rather than handing off from one material handling/sorting arm to another to move a waste item laterally, a segregated item of waste is placed in a specially designed basket hung from the remotely controlled underhung bridge crane and moved to the conveyor servicing the specified treatment glovebox.

Oversized objects are directed to a sizing cell where mechanical shears reduce the objects to sizes suitable for packaging into drums or SWB insert containers. These containers are then conveyed to the box assay staging area for sampling and assay operations.

Full drums are directed via conveyor to a drum-processing cell. There the drum is opened and its contents are dumped on a tray-type sorting table. Operators utilizing remotely operated equipment sort and direct the drum and its contents as follows: the empty drum, the drum lid, are routed to the shredder, sludges are packaged into SWB insert containers and routed to the box assay line staging area, any non-shreddable and non-inventoried items (containers with solvents, etc.) are packaged in drums identified for outlier objects. The drums are stored in a remote warehouse for future disposal.

Any free liquids are stabilized. All other contents are directed to the shredder. Cardboard boxes, bundled combustibles, plastic wrappings, empty drums, lumped wastes and soils, and loose, thin metal objects are routed directly to the shredder from the Sorting Deck. Non-inventoried items are packaged in outlier drums, un-shreddable items are packed in drums and routed to the box assay line staging area.

When there is nothing left on any of the three zones on the deck except loose soils and wastes, that zone's walking floor conveyor is utilized to convey these products and discharge them to the 5 ft wide grid covered slot which extends the entire length of the table. The grid is sized with 4 in. x 4 in. openings to restrict the size of materials that can report to a conveyor below. A large collection hopper below the grid directs product to the soils collection conveyor that transports and transfers the product to the screen feed conveyor.

The screen feed conveyor transports, elevates and discharges the product stream to the disc screen. The screen allows minus 60-mm material to fall through to a conveyor system that then routes it to a staging bin at the bulk/belt assay cell. The plus 60-mm material is discharged from the screen to the conveyor system feeding the shredder.

Material handling of the organic setups is quite likely to be one of the greatest challenges associated with treatment of the contents of Pit 9. The organic setups consist of Texaco regal oil, carbon tetrachloride, and other organic contaminants and calcium silicate that were added to stabilize the liquid. The solidified material has been described (Clements Report) as having the consistency of paste or grease. Data from the GEM operations will provide better data regarding the container integrity and physical properties of this material but it is likely that this paste-like material will be difficult to manage.

About 1140 drums of organic setups were disposed of in Pit 9. Some of these drums are likely to be degraded. Descriptions from the Clements Report indicate that separation of the organic contaminants from the calcium silicate may have occurred. The combination almost certainly ensures that there has been contamination of surrounding soil with organic liquids, so the treatment system will have to accommodate both contaminated soil and the contaminated paste-like material.

From a material handling perspective, the contaminated soil should be relatively easy to manage and will be handled with the rest of the soil. The soil will be transferred from the Sorting Deck to the soil transport conveyor and then to the soil screen. Soil passing through the soil screen would then be stored in small hoppers, for process control, and then carried by conveyor to the assay systems. Samples would be taken from the assay belt for analysis for RCRA hazardous constituents.

The paste-like setups, however, will pose more of a material-handling problem. The proposed approach is to identify the organic setups during retrieval so that special plastic "skid plates" or "tubs" can be placed at the Sorting Deck to facilitate moving the material across the sorting deck. The organic setups would be transferred to the Intact Drum/Special Materials Glovebox, which is located at one end of the sorting deck. The material would be transferred into new plastic containers, similar in size to 55-gallon drum liners. This repackaging effort would be accomplished such that the WIPP criterion for

visual examination of the package waste would be met because, at this stage in the process, it is not known if this material is TRU or not. The plastic container would be transferred to the box/drum assay system where it will be assayed. If the container is TRU ($> 100 \text{ nCi/g}$), it will be overpacked in a 55-gallon drum and placed into the WIPP certification process. If the container is not TRU, it must be treated before being returned to the pit. These non-TRU organic setup containers will be “stockpiled” until several (approximately 10 or more) have been collected. These containers and an amount of soil (the amount to be determined from future development testing) will be processed concurrently through the shredder. The shredder will provide the capability to assure that the organic setup and soil are sufficiently mixed that the material handling properties are sufficient for transfer to the thermal desorption system.

The shredder reduces the infeed materials to minus 60-mm products. These are then routed to a packaging station where they are packed into SWB inserts that are then routed to the box assay cell staging area.

The waste products in both assay staging areas are fed to the assay units at rates and intervals that meet the requirements of the assay units. Sampling and analysis for VOCs is also performed during this phase. As the waste streams emerge from the assay cells, they are directed to any of several staging and packaging areas to prepare them for further disposition.

If the fully characterized waste meets all criteria for return to Pit, it is packaged in special Return Waste Boxes. These are nominally sized at 5 ft x 5 ft x 6 ft high. They can accommodate either bulk or packaged wastes. After these boxes are packed with waste products, grout is pumped into them to assure that all voids are filled and that the containers are structurally stabilized. The containers are then lidded, sealed and routed to staging, in a separate warehouse holding area, for eventual return to Pit 9.

Waste products meeting the criteria for transfer to the WIPP facility are routed to a packaging staging area for WIPP-approved packaging, to a packaging cell for packaging for further treatment, or in the case of wastes already packed in 55-gallon drums, direct to treatment. Depending on the types of additional treatment processes that may be employed, the waste products for WIPP may be re-packaged in re-usable tote bins for in-process surge storage.

The characterization area operates 24 hours per day. All components and sub-systems are designed to process a minimum of $2 \text{ m}^3/\text{hour}$ or 48 m^3 of retrieved waste per day.

Equipment Description/Selection Basis

The various individual equipment items and the discrete mechanical process sub-systems located in the Characterization Area were selected not only for their direct applicability for their designated functions, but also for their proven designs, their robustness of construction, and their minimal maintenance requirements. All equipment items functional capacity far exceeds the actual design requirements. This is the result of conservative equipment sizing, selection of individual components for their durability and historically proven reliability and, sizing items and components so that maintenance requirements are minimized. Conservative sizing, primarily for volumetric dimensions, is important because of the unknown condition of the retrieved waste containers. Volumetric dimensional data are based on available inventory records of wastes buried in Pit 9 (OU 7-10). The largest anticipated containers buried in the pit are 5 ft x 5 ft x 10 ft long. There are also references to bundled wastes that contain everything from office furniture, 100 feet of gloveboxes, demolition debris, and unknown items. No solid information is provided for these bundled waste dimensions. It is anticipated that all intact

bundles will be opened and sorted on the Sorting Deck. This is also true for all other containers except 55-gallon drums. Following is a brief discussion of the major equipment items selection basis.

All equipment specified for the characterization area was selected specifically for its suitability for the operations, tried and proven track record, robustness of construction, ability to be remotely operated, and minimal maintenance requirements. Additional design requirements that the selected equipment can accommodate are, where possible, utilization of hydraulic drives with only the actual hydraulic motors and cylinders in the enclosed work cells. The actual hydraulic units are to be located in a remote Zone I area. Equipment is furnished in unitized modules to allow easy replacement/removal and all equipment items utilize standard and commercial readily available components.

Conveyors

Conveyors are the most critical aspect of the entire Characterization Facility. They are required to move both bulk and unit type loads. They must accommodate variations in bulk densities, moisture contents, particle and unit sizes, feed rates, and severe impact loadings. The conveyors provide controlled feed rates to the various individual mechanical processes. They must be able to operate continuously in an extremely adverse environment. The conveyors must also have the capability to stop and restart, fully loaded, due to equipment upsets or special process requirements and most importantly, the conveyors are expected to perform their functions for the life of the facility with no major breakdowns. For simplicity of design, spare parts inventory, and operator familiarity, the number of types of conveyors and the different sizes of conveyors will also be minimized.

The three most common types of conveyors that meet the above criteria are vibrating type pan conveyors, belt conveyors, and apron conveyors. Vibrating conveyors have limitations on length and are not suitable for elevating the conveyed loads. For these reasons vibrating conveyors were eliminated from further consideration. Belt conveyors are by far the most common type of conveyors utilized for similar applications. Several inherent characteristics of belt conveyors, while not normally serious drawbacks, can be major problems for applications requiring enclosed and isolated operating conditions. The belting itself while quite durable is subject to damage from sharp edges-such as from metal debris, damaged drums, etc. This type of damage can be addressed by replacing a section or even the entire length of the belting. This is not a good activity to undertake in areas contaminated with radioactive waste residues. Belt conveyors do not like severe shock or impact loading. These actions can cause the belting to run off track (center), damage the belting edges, spill material, and shut down the system. In applications where operator interface is not an issue, these mishaps can be readily addressed. Again, in areas contaminated with radioactive waste residues direct operator interface should be minimized. Fire retardant belting is available and commonly used. However, should a combustion incident occur, the belting would be damaged and require partial or entire replacement. The third type of conveyor, apron conveyors, is able to tolerate the above negative conditions without sustaining damage and/or requiring direct operator interface.

The carrying belts of apron conveyors are constructed of overlapping u-shaped formed metal plate sections. These sections form a continuous carrying surface (similar to a belt conveyor). The u-shape contains both loose bulk and unit loads. Because the entire width of the carrying section is formed from a single piece of metal plate, there is no gap for materials to leak through or become wedged under, as there would be with a standard belt conveyor and skirt boards. The overall heavy-duty construction of apron conveyors, which can be tailored to specific applications, allows them to absorb shock loads and mixed feed conditions without being negatively impacted. An apron conveyor, like all continuous type conveyors, will experience some carry back and dribbling of material along the entire length of its return

run. To address this problem, all apron conveyors will be furnished with clean-up drag conveyors situated below them to continuously capture any dribble and convey and discharge that material to the same point as the apron conveyor.

Apron conveyors are utilized in the characterization area for all conveying applications of as-received wastes, bulk wastes, and inter-process handling to packaging operations. After wastes are packaged in new and stable containers, chain driven live roller conveyors (CDLRs) are utilized for handling and conveying of the packed waste containers to further treatment, surge storage, or other functions. Heavy-duty roller conveyors have been and are used in similar applications throughout the world. They are a reliable and proven type of conveyor for handling various shaped, sized and weight of unit loads. They are a cost effective, reliable and durable means of fulfilling the requirements of the characterization facility.

Material Handling Arms

Three material Handling Arms are provided at the Sorting Deck. These units are pedestal mounted and remotely controlled. Their primary function is to sort all of the wastes received on the deck. The arms are very similar to backhoe equipment boom arms. They have different end effector attachment mechanisms to allow for changing out different end effector attachments (shovel, grapple, two or four tine roll clamps, barrel handlers, etc.). The arms are hydraulically powered and have a long history of reliable operations.

Shredder

A “Komar” Tri-Auger shredder is provided for size reduction of retrieved waste products. This particular brand name and type of shredder is used throughout the world in very similar applications. The unit’s over-all robustness of construction and reliability has made it the top choice of numerous hazardous and radiological waste treatment facilities. The tri-auger design requirement is dictated by the needs of additional treatment processes that can handle only wastes with a maximum constituent size of minus 60 mm.

Screen

A disc type screen is provided to separate from the retrieved soils stream oversized materials greater than 60 mm that have passed through the grizzly grid. Disc type screens utilize rotating discs, instead of vibration, to convey the incoming feed across its deck area. The smooth operation of this type of screen eliminates not only the high noise level associated with vibrating screens but also the majority of problems associated with vibrating equipment. Usual problems such as drive motor failures, broken seals, loosened mountings, necessary flexible connections and equipment fatigue failures, are minimized by using this type of screen.

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Appendix B

Process Description for Thermal Desorption

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Appendix B

Process Description for Thermal Desorption

Thermal Desorption of Soils/Sludges

Process knowledge of the waste in Pit 9 indicates that volatile organic compounds (VOCs), including carbon tetrachloride, trichloroethane, trichloroethylene, perchloroethylene, and semi-volatile organic compounds (SVOCs), including Texaco Regal oil, were present in the waste when it was disposed in Pit 9. As container integrity was compromised, these compounds are expected to have migrated into the soil matrix surrounding the waste. Some of these organic compounds are RCRA hazardous constituents, and must be removed before non-TRU soil can be returned to Pit 9 for disposal. To address the problem of organic material in the waste, thermal desorption was selected to remove the organics from the soils and sludges prior to leaching.

Soils and sludges that have $\leq 100 \text{ nCi/g}$ TRU contaminants will be processed in a thermal desorption unit to remove hazardous VOCs. TRU ($> 100 \text{ nCi/g}$) soils will also be treated to remove VOCs as a first step in the process to decontaminate those soils. Feed from the assay and pretreatment system will be stored in a hopper to allow a continuous feed to the thermal desorber. The hopper will be sized to hold at least 24 hours of feed or approximately 20 m^3 of material. The hopper will be connected directly to the desorber to reduce the flow of air into the TD system and to reduce fugitive emissions.

The volatility of the organics present affects the processing rate in the thermal desorber. Highly volatile compounds will desorb at relatively low temperatures, especially if vacuum is applied. This will reduce the batch time if the less volatile compounds can remain in the matrix. Less heat up reduces not only the energy and time necessary to raise the temperature of the waste matrix, but will also reduce the time required to cool the waste before it can be removed from the system. The RCRA-regulated VOCs can be removed at temperatures less than 125°C , with perchloroethylene having the highest boiling point at 121°C . Having the desorber operate at 175°C should provide sufficient thermal driving head to ensure that all VOCs have been removed by the process. Because the SVOCs present in the waste are not hazardous, their volatility is not an issue, and they will be returned to Pit 9 with the bulk of the non-TRU waste.

The relatively low operating temperature of 175°C will also prevent volatilization of significant quantities of mercury or semi-volatile metals, such as cadmium if they are present. However, activated carbon beds in the off gas will capture any mercury or other metals in the event that they are desorbed or entrained in the thermal desorber off gas.

The bulk of the thermal desorption units available from the commercial sector have a capacity for treatment up to 20 times greater than required to meet the present Pit 9 design basis. Many are rotary kilns that use high sweep gas flow rates that would be inappropriate for the small particle Pit 9 waste. Two small-scale thermal desorbers have been used to treat DOE waste, but would require multiple units to treat the expected throughput. The interfacing of multiple units is deemed too complex to be practical for the Pit 9 process, so these were not considered further.

The unit that was selected for the Pit 9 process is a “Holo-Scru” Dryer manufactured by Unico Services, Inc. This unit can easily be sized to meet the Pit 9 requirements. The process can also achieve negative pressure or vacuum, eliminating fugitive emissions from the system. The “Holo-Scru” Dryer

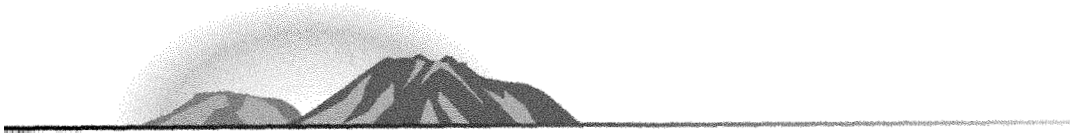
circulates hot oil at 260°C through two hollow-flight screws, heating the waste as it is moved through a jacketed W-trough housing. The final configuration will have to be determined in the detailed design phase when exact vacuum requirements have been determined. The screws have 16-in. nominal diameter flights, a 16-ft working length with a 4-in. pitch mounted on 6-in. pipe shafts. The material of construction is carbon steel. Shaft seals are designed to prevent loss of material or gases from or the flow of gases into the system.

The desorber will be operated at about 175°C to remove only the hazardous VOCs and leave the SVOCs and hazardous metals in the waste. The system will operate under negative pressure to eliminate fugitive emissions. Steam will be used as sweep gas to move the vaporized organics to the condenser. A boiler will supply superheated steam to the dryer at approximately 39 kg/h. Use of steam as the sweep gas will increase the load on the condenser, but decrease the load on the off gas system. Only non-condensables entering with the waste and fugitive condensables will go into the off gas system.

Off gas from the thermal desorber will pass to a condenser where the organics and water will be condensed. Graham Corporation makes a shell and tube condenser that will handle the vapor streams generated by the thermal desorber. The Graham VCT Heliflow Vent Condenser condenses the vapor stream on the tube side, giving more positive control of the possibly radioactive stream. This unit allows condensate to be piped into a tank, instead of draining off the outside of the tubes into a catch tank, giving more positive control of the condensate. The vent condenser can operate at the required negative pressure. Design vapor inlet temperature would be 175°C, while condensate temperature would be 50°C. The design throughput for the condenser would be 310 kg condensate per hour, assuming 93% water and 7% organics. This would allow sufficient additional condensing capacity to account for unforeseen moisture in the waste.

The majority of the organics are relatively insoluble in water, so a settling tank will be used to produce a neat organic stream that will be sent offsite for destruction. A 600-gallon settling tank will provide 8 hours for the organics to coalesce and separate. The organic phase will be pumped to a holding tank, from which it can be pumped to suitable containers.

It is assumed that the condensed water could contain up to 1% of the incoming organics, so the aqueous condensate will be pumped to an adsorption system consisting of two beds in series. A Bonifiber bed would be used as an initial sorption step to separate organics from water. Bonifibers will adsorb 25 times their weight in organics, such as oil and similar organics, but are not suitable for halogenated organics. An activated carbon filter will be used to remove halogenated organics from the water. For the low flows anticipated in this application, canisters of activated carbon can be used. When the carbon becomes saturated with organics, it can be recycled through the thermal desorber. Ultimately, the spent carbon will be sent offsite for processing. The clean water will be processed in an evaporator.



Appendix C

Process Description for Melting

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Appendix C

Process Description for Melting

Introduction

This alternative will vitrify all the soil, sludge, and shredded debris excavated from Pit 9 that is >100 nCi/g and is destined for disposal at the WIPP. It is assumed that additive materials to be mixed with the dirt/shredded wastes will make up no more than 10% of the melt chemistry.

Melter Feed System

Feed from Retrieval

During retrieval operations, debris, soil, and sludge will be sorted, sized as needed, analyzed, and packaged in tote bins, which will be delivered to the melter feed system. These tote bins will have a volume of approximately 3 m^3 and will require changing about twice per 8-hour shift.

Shredded Solid Feed

The shredded debris feed subsystem will consist of the tote bins of shredded debris, a metering auger, and isolation valves to facilitate changing the tote bins and for auger maintenance. The auger will be capable of handling materials up to 2 inches square at a rate of 0.02 m^3 per hour. The shredded material will be gravity fed to the auger, which will control the feed rate of the shredded material into the melter. From the auger, the material will be gravity fed directly into the melter. The auger will be one of the higher maintenance items in the melter system. Replacement augers should be available for rapid change-out.

Soil/Sludge Feed

The soil/sludge feed subsystem will consist of the tote bins of soil and sludge, a metering auger, and isolation valves to facilitate changing the tote bins and for auger maintenance. The auger will be capable of handling materials up to 2 inches square at a rate of 1 m^3 per hour. Because the soil will be the primary feed of the melter system, an installed spare auger may be required to allow maintenance and replacement without shutting down feed to the melter. The dirt will be gravity fed to the auger, which will control the feed rate of the dirt into the melter. From the auger, the material will be gravity fed directly into the melter.

Additive Feed

Because of the uncertainties associated with the amounts and compositions of the soil, sludge, and shredded debris to be fed to the melter, it may be necessary to introduce additives into the melter to improve melting rate or product quality. Dry additives, such as sand, glass frit, fluxing agents, or redox control agents, may need to be added. The additive feed subsystem provides the ability to add these dry agents if required. The additive feed subsystem will consist of a storage bin of the required additive(s), a metering auger, and isolation valves to facilitate auger maintenance. The auger will be capable of handling materials up to 2.5 inches square at a rate of 0.1 m^3 per hour. This is based on the assumption that the additive materials will make up not more than 10% of the melt chemistry. The auger will control

the feed rate of the additives into the melter. From the auger, the material will be gravity fed directly into the melter.

Liquid Feed

A liquid feed subsystem is also provided. This will allow liquids wastes or secondary wastes (such as off gas scrub recycle) to be fed to the melter in conjunction with the soil/sludge and shredded materials. The sub-system consists of a 1,900 L tank that can be agitated and sampled. Sampling of the liquid waste will be required for WIPP qualification prior to adding the liquid to the melt. Valves for isolation and a liquid feed pump with metering capability (or a metering valve), to control the rate at which the liquid waste is fed into the melter, make up the remainder of the equipment. At this stage of the design the amount of the scrub recycle is not known so the sizing of the tank and pumps capacities are only estimated. Pu carryover is expected to be small but testing and evaluation will be needed to determine if there is any chance of Pu concentration to the extent that criticality must be addressed by geometry or other techniques.

Melter System

There are a number of different types of melters that have been used for waste vitrification. These include joule-heated, induction, plasma torch, and arc melters.

Joule-heated melters have lower temperatures ($> 1200^{\circ}\text{C}$) and require tightly controlled melt chemistry to control viscosity and electro conductivity of the melt. Because of the higher melting point of INEEL soil and the uncertainties of the waste composition, Joule-heated melters were not selected.

Induction melters have the higher temperature capability required, but, to date, the throughput capacity required for Pit 9 has not been proven, so induction melting was not selected.

Both plasma-torch and arc melters have the high temperature and throughput capacity required for processing the soil/sludge and shredded debris from Pit 9. A rotating-hearth plasma torch melter was considered. The main advantage being that the plasma arc “indents” into the melt while the melt rotates and stirs the melt. This results in any metal phase being easily stirred into the melt and oxidized by torch gases. The torch gases can be modified as necessary to adjust the redox of the melt. The major disadvantage to this melter is that the rotating hearth is large and complex with many moving parts, which makes maintenance very difficult. Also, plasma-torch melters do not idle well (no feed and reduced temperature) for extended periods. Torches also must have torch gases fed at all time for the torch to function. This adds to the off gas burden.

Fixed-hearth arc melters use graphite electrode to generate an arc within the melt. These melters are similar to some metal smelters that have been sized to very large capacities. They have no moving parts, except for the electrodes, which are slowly lowered into the melter as they erode and oxidize. New sections of electrode are added as needed. No gas is required to sustain the arc. One disadvantage is that the melting environment is reducing, because of the graphite electrodes, which can cause a separate metal phase to form in the bottom of the melter. To alleviate this and make the melt more oxidizing, oxygen can be bubbled into the melter. Graphite-arc melters can be idled for weeks or months and started up again with few problems.

Either of these two general types of arc melters could be used for vitrification of the Pit 9 waste. The fixed-hearth arc melter was selected for this study due to the simplicity of design (and lack of

maintenance under contaminated conditions) and the ability to be scaled up to higher throughput rates if required. There are specific types of arc melter that could be considered, such as AC or DC arc. However, at this point in the design both would have very similar cost and basic design requirements and outputs. The decision as to which type of arc melter that should be used is left for conceptual design.

Melter/Power Supply

The arc melter will have a throughput capacity of greater than 1000kg/hr. This will require a power supply of approximately 1,500kW and a melt surface area of approximately 1.5m². Melt temperatures will range from 1,100°C to 1,650°C. The melter will be refractory lined with a water-cooled metal shell. The soil/sludge and shredded debris should be added to the melter at such a rate that there would be a "cold cap" of unreacted material on the surface of the melt. This will reduce the temperature in the plenum of the melter and will reduce the volatility of metals from the melt.

Electrode

As the graphite electrodes erode and oxidize, the electrodes are slowly lowered into the melter. New sections of the electrode are added as needed.

Melter Drain

Glass is typically removed from a melter through a bottom drain or through an overflow/weir drain. Some melters have both types of drains. For the Pit 9 melter, a bottom drain was chosen. Because the drain has been found to be the primary failure mode for melters, multiple drains should be included in the melter. The bottom drain will have heaters to initiate glass flow and cooling to assist in stopping the glass flow. There may also be a need for mechanical means such as a specially-designed, cooled, slide valve to stop the glass flow. The drain will also have the ability to remove any metal phase that collects in the bottom of the melter.

Glass Sampling and Slag/Glass Collection System

The glass will be poured directly into 55-gallon drums. Glass poured into drums will blister any paint from the outside of the drum and oxidize the surface but the drum will remain intact. However, if metal collects in the bottom of the melter and is discharged directly into an unlined drum, the drum will deform and possibly melt. Refractory lined drums could be used if a second metal phase is suspected. As the glass leaves the melter, provisions for taking glass samples must be made. This could be a mechanical probe that collects some glass in the pour stream from the drain in a graphic mold or the collection of glass shards that spill off the top of the glass in the drums as it cools.

Off gas System

Introduction

Although the melter is not technically a hazardous waste combustor, the off gas system is designed to reduce contaminant emissions sufficiently to meet or exceed the provisions of the Maximum Achievable Control Technology for Hazardous Waste Combustors (MACT). In addition, NO_x emissions will be reduced to prevent a visible plume from the stack. The MACT limits are as follows:

Contaminant	MACT Emission Limit
Hydrocarbons	20 ppmv
Carbon Monoxide	100 ppmv
Chlorine/Hydrogen Chloride	21 ppmv
Low Volatile Metals	97 µg/dscm
Semi-volatile Metals	120 µg/dscm
Mercury	45 µg/dscm
Particulate Matter	34 mg/dscm
Dioxin/Furan	0.2 ng/dscm

Thermal Oxidizer/Secondary Combustion

The off gas leaving the plenum of the melter contains unburned hydrocarbons, acid gases, volatile metals, and particulate matter (PM). The off gas from the melter first passes to a thermal oxidizer where it is reacted with added combustion air to completely oxidize residual products. This thermal oxidizer will be propane fired. The combustor outlet temperature is about 890°C (1,640°F).

Partial Quench

Following the thermal oxidizer, the off gas is rapidly partially quenched to about 120°C (248°F) using a caustic scrub solution from the scrub solution hold tank. In addition to cooling the off gas, the quench will remove a portion of the PM and acid gases.

Scrub System

Residual PM and acid gases are captured in the caustic scrubber. The scrubber provides intimate contact with the scrub solution and off gas in order to effectively scrub volatile species (e.g., HgCl₂, HCl and HF) and PM, and also provides additional cooling to the off gas.

The water used for quenching and scrubbing the off gas will incorporate various contaminants from the off gas. The quench/scrub water will be maintained at about pH 7 by the addition of fresh caustic. A blowdown stream from the scrubber will maintain the scrub solution at about 35% NaCl. Two options exist for the blowdown stream. As much as possible of the blowdown water is to be a recycled to the melter for vitrification. If the blowdown stream is too large for recycle to the melter, the blowdown will be solidified in grout with a sodium chloride concentration of about 25%. The blowdown will contain relatively small amounts of TRU species, so will be returned to Pit 9 or sent to a suitable landfill for ultimate disposal.

High Efficiency Mist Eliminator

A high-efficiency mist eliminator (HEME) is placed downstream of scrubbers to remove entrained water for the off gas. The HEME is used to collect fine particles in addition to water droplets. The HEME filters employ a single, large, cylindrical, packed fiber bed. Off gas enters in the central annulus of the bed and process water is allowed to flow down the inner face of the coarser, less densely packed fiber bed to

minimize the accumulation of vapors and particulates on the bed. Wicking is prevented by control of the water and off gas flow rates. The filter is washed when the pressure drop across the element reaches a predetermined level. These units are used when the existence of fine aerosols creates a pressure drop buildup across the HEPA filters. Due to the diffusion collection mechanism of the HEME, it should be sized fairly conservatively in order to maintain face velocities less than 5 ft/min.

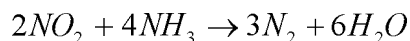
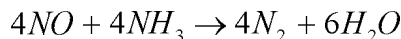
Reheater

The reheater is needed to increase the off gas to a temperature that smoothes the operation (temperature control) of the SCR.

NO_x Removal

Although the level of NO_x is not expected to be high, NO_x reduction will be used to ensure that emissions are within regulatory limits. Other benefits to NO_x reduction include minimizing interference with the measurement of volatile organic emissions and elimination of a visible plume. Options for NO_x removal include multistage combustion, SCR, and selective non-catalytic reduction (SNCR). Because of its demonstrated capabilities, SCR has been selected for the Pit 9 process.

A propane burner will heat the off gas to about 400°C and then ammonia will be injected into the gas stream. The ammonia to NO_x ratio will be about 0.9 to prevent excessive ammonia slip. The SCR will reduce NO_x emissions by greater than 95%. Due to the addition of ammonia gas, the reactions in SCR for NO, destruction are:



Ammonia will be supplied from a 1,000 L ammonia tank, which will require filling approximately 15 times over the three-year operating period.

Heat Exchanger

The purpose of this heat exchanger is to reduce the hot gases from the SCR to about 80°C prior to the activated carbon beds.

Mercury Adsorber

To ensure that mercury emissions will be within regulatory limits, an adsorber containing sulfur-impregnated, activated carbon will be used. Incoming off gas is about 70°C to 80°C and for the relative humidity must be below about 50%. Although no mercury is known to be present, the adsorption bed will be sized to remove about 100 kg of mercury over the two years of operation. Assuming a 10% capacity for mercury on the carbon, the adsorber will contain about 1,000 kg of carbon. The carbon bed will have a residence time of about 3 seconds and a superficial velocity of about 0.3 m/s. The mercury adsorption bed is designed to last the duration of the campaign and will be disposed of as mixed low-level waste upon completion of Pit 9 remediation. In addition to mercury, it is expected that iodine and technetium (I-129 and Tc-99 radioisotopes) would also be adsorbed onto the S-GAC.

HEPA Filters

HEPA filters, with a PM removal efficiency of 99.97% at 0.3 μm , will be used to remove the remaining particulate matter. Roughing and HEPA filters will be replaced when the differential pressure across the HEPA filters exceeds specifications. They will then be compacted and, if greater than 100nCi/g TRU, they will be shipped to the WIPP for disposal.

Off gas Blower

An induced draft blower is used to provide the negative pressure on the off gas system. This blower should be oversized to allow for surges in the process and still maintain negative pressure on the system. Constant negative pressure cannot be maintained by the blower alone, because the reaction time on the blower is much larger than the surge durations. To provide for constant negative pressure and a constant blower speed, an air purge before the blower will be adjusted to maintain flow through the blower.

Drum Handling

Drum Conveyor

The drum conveyor will move new, unpainted, unlined, 55-gallon drums from storage to a point under the melter drain. Molten glass will be poured directly into the drum. The conveyor should be designed to dissipate the heat transferred from the glass, through the drum, and into a large heat sink on the conveyor. This may be a single line conveyor or a multiposition conveyor that moves the drum on and off the conveyor into filling and cooling stations.

Drum Cooling

When glass is poured into the drum, the surface of the drum will heat rapidly. However, because of the low thermal conductivity of the glass and the high thermal conductivity of the metal drum, the glass just inside the surface of the drum will cool rapidly and slow the heat transfer to the outside surface of the drum. After approximately 24 hours, the outside surface of the drum should be below 100°C. The centerline of the glass in the drum will be much hotter. The drum must now be allowed to cool before the drum lid can be installed. The drum lid contains a polymer gasket that will be damaged at temperature over 100°C. A temperature cover should be placed on the surface of the glass to stop shards of glass from being ejected from the drum due to the spalling of the glass surface from rapid cooling.

Remote Drum Lid Installation

After the drum has cooled to the point where the lid gasket will not be damaged, the permanent lid will be installed on the drum. Modeling of the drum filled with cooling glass will be required to finalize the time required.

Smear and Decontamination

WIPP requires that the outside surface contamination of the drum be less than 20 dpm/100 cm^2 alpha and 200 dpm/100 cm^2 beta-gamma. Each drum will be swiped to determine the surface contamination on the drum. If the drum surface contamination exceeds the WIPP requirement, the surface of the drum will be decontaminated.

Mechanical Uncertainties

There are melter designs that have been built for nuclear waste treatment applications but they have not been demonstrated on streams with high alpha contamination on a production basis. The melter system will have some of the same design challenges as the TRU incinerator.

The feed and discharge systems must be designed to assure isolation of the contaminated, high temperature environment from the environment. The proposed feed system concept for this study is a series of valves that are operated in sequence to keep the feed hopper isolated from the kiln. This scheme must be further developed to assure that material flow problems and impact of high temperatures (causing the feed to become “sticky”) are identified and addressed. The slag tapping system design will also have to address confinement of the contaminated material.

The fact that some of these contaminants are fissile is another major concern. While it may be unlikely, systems must be put in place to assure that fissile material does not accumulate in the system (feed, kiln, or discharge). This control system was not evaluated as part of this study and will have to be addressed in subsequent design efforts.

Maintenance of the melter in the contaminated environment is also a significant challenge. The refractory lining of the melter will have to be inspected periodically and eventually replaced, if the Stage III treatment facility is used to remediate other pits and trenches. Water-cooled crucibles might be used but these have their own set of problems. Removal and replacement of spent electrodes in this system will also be much more complicated than installations that are not concerned with the high levels of alpha contamination.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000



Appendix D

Incineration Systems Descriptions

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000



Appendix D

Incineration Systems Description

Introduction

The TRU incinerator system will provide thermal treatment of pre-conditioned TRU mixed wastes from Pit 9 at the INEEL. While the concept of an incinerator system is feasible, major uncertainties remain in both the process and mechanical designs. The process uncertainties derive from the fact that both the pit contents and the processes that produce incinerator feeds from the pit contents are, as yet, poorly defined. The systems used in this study were based on assumed nominal compositions and rates of the three feed streams to the incinerator. All feed streams to the incinerator will contain $> 100 \text{ nCi/g TRU}$ and will be derived from three sources:

1. Shredded debris waste ($\sim 60 \text{ kg/h}$) containing combustibles, steel, and other non-combustibles
2. Organic liquid condensate ($\sim 9 \text{ kg/h}$) from thermal desorption of soil, sludge, and debris fines ($< 60 \text{ mm}$). Primary constituents will be carbon tetrachloride, trichloroethane, trichloroethylene, and perchloroethylene, with small amount of ethanol, EDTA, and ascorbic acid
3. Sludge ($\sim 250 \text{ kg/h}$) from oxalate precipitation of liquor derived from chemical (HNO_3) leaching of soil, sludge, and debris fines. In addition to oxalate complexes with TRU components, the sludge will contain about 98% calcium and magnesium oxalates.

These streams will be incinerated to reduce the volume and toxicity of waste constituents, and to produce a dry, solid ash that is suitable for transport to and disposal at the Waste Isolation Pilot Plant (WIPP).

A wide variety of incinerator options could be used to fulfill the primary requirements, including a rotary kiln, single or multiple hearth, stoker grate, batch mass burner, or virtually any other type of fired chamber that will convert the waste materials to off gas and stable solid ash. To support preliminary planning and budgeting, a non-slugging, rotary kiln was selected. Although several manufacturers are available, a design provided by Andersen 2000, Inc. is used in this description. The incinerator system is comprised of propane-fired primary and secondary combustion chambers, associated feed systems, and an ash removal system. The system is designed to achieve at least 99.99% destruction of all hazardous organic constituents in the feed. An off gas system will treat the off gas to meet all applicable emission requirements. All major equipment will operate under slight negative pressure to help prevent the spread of alpha contamination.

The mechanical uncertainties associated with the rotary kiln (and to some extent, any incinerator system) are driven by the special requirements for confinement of alpha contamination. Items such as feed and discharge systems, rotating seals on the kiln, kiln inspection and maintenance and Pu holdup concerns (criticality).

TRU Incinerator System Description

A discussion of the major components of the incinerator systems are provided below for the TRU incinerator used in Alternative 4a.

Primary Combustion Chamber

The primary chamber is a 1.6m ID refractory-lined, rotating kiln. The kiln will be rotated between 0.2 and 2.4 times/min. by a 30 HP gear drive motor. The three waste types are fed to the incinerator through separate feed systems. Shredded debris is fed either loose or prepackaged in cardboard boxes (up to 2 ft by 2 ft by 3 ft) through an airlock hopper into a ram feeder. Liquid wastes are pumped from a 7.5 m³ feed tank through a pressurized nozzle directly into the flame zone of the kiln. Sludge waste is fed from a 2 m³ sludge bin using dual ribbon flight conveyors powered by a 5 HP motor to a 5 HP positive displacement sludge pump and then to the incinerator. Maximum heat release in the kiln, including the secondary combustion chamber is about 7.5 MMBtu/h. Actual firing rate will be about 2.5 to 3 MMBtu/h. The residence time in the primary combustion chamber is at least 3 seconds, which provides sufficient thermal energy and residence time for initial vaporization, oxidation, and gasification of volatile and combustible waste components.

Ash will be discharged from the primary combustion chamber into an ash cooler where it will be cooled to ambient temperature for packaging, assaying, and shipping. Ash discharge and packaging will be accomplished in specially designed airlock and decontamination enclosures to prevent spread of alpha contamination. Approximately 80 kg/h of hearth ash will be discharged from the primary combustion chamber and a further 55 kg/h of dust will be added from the cyclones discussed below. Ash and dust will be comprised of the non-combustible fraction of the debris waste, together with metal oxides, re-burned concrete and sorbents, calcined soil components, and some refractory char. Ash particulate matter will range in size from approximately 50 mm down to sub-micron dust. Incinerator ash will be TRU contaminated and will be shipped to the WIPP for ultimate disposal. About 1,300 metric tons of incinerator ash will be produced during Pit 9 remediation.

The refractory linings in the primary and secondary combustion chambers, hot cyclones, and associated hot ducts should have sufficient lifetime to last the duration of the processing campaign, so will only require disposal at the time of decommissioning.

Secondary Combustion Chamber

Hot off gas from the primary combustion chamber will be fed directly to a vertical, refractory-lined secondary combustion chamber. Supplemental propane and air will be supplied through the secondary burner. The secondary combustion chamber provides a minimum 2-second residence time at 1,100°C to ensure complete destruction of toxic or hazardous organic species in the off gas from the primary combustion chamber. The secondary chamber volume is to be about 14m³ yielding a maximum off gas flow rate of about 22,000 m³/h.

Off gas Treatment System

Introduction

The off gas system is designed to reduce contaminant emissions sufficiently to meet or exceed the provisions of the Maximum Achievable Control Technology for Hazardous Waste Combustors (MACT). In addition, NO_x emissions will be reduced so as to prevent a visible plume from the stack. The MACT limits are as follows:

Contaminant	MACT Emission Limit
Hydrocarbons	20 ppmv
Carbon Monoxide	100 ppmv
Chlorine/Hydrogen Chloride	21 ppmv
Low Volatile Metals	97 µg/dscm
Semi-volatile Metals	120 µg/dscm
Mercury	45 µg/dscm
Particulate Matter	34 mg/dscm
Dioxin/Furan	0.2 ng/dscm

Testing will be required to determine the chemical composition of the off gas and the amount of carryover of radioactive material from the primary and secondary chambers to the off gas treatment system.

Cyclone

Off gas from the secondary chamber will pass to dual refractory-lined cyclones. Particulate matter greater than about 40 µm will be removed from the off gas and will be returned through dual water-cooled ducts to the incinerator ash collection system for packaging and shipping.

Scrub System

From the cyclones, the off gas will pass to a Triven scrub system, also supplied by Andersen 2000, where it is first quenched and then passed through three venturi scrubbers in series. Caustic solution, used as the quenching and scrubbing solutions in the venturis to remove acid gases, will be recirculated through a water-cooled heat exchanger. Provision is included for caustic blowdown when the chloride content reaches about 20% or when the solids content reaches about 10%. The blowdown solution will be stabilized with cement and returned to Pit 9. Make-up caustic (50%), supplied from a 1,000-gallon tank, will be used to maintain the scrub solution at a pH sufficient to facilitate removal of acid gasses. Scrubbed off gas will pass through series mist eliminators to remove entrained moisture and particulate.

Caustic scrubber blowdown will be produced at the rate of about 3 L/min. This blowdown stream will be about 35% NaCl. Blowdown will be solidified in grout with a sodium chloride concentration of about 25%. The blowdown will contain relatively small amounts of TRU species, so will be returned to Pit 9 or sent to a suitable landfill for ultimate disposal. Approximately 1,000 m³ (1,600 metric tons) of solidified scrubber blowdown will be produced during Pit 9 remediation.

About 5 MMBtu/h (5.3 GJ/h) must be rejected to a cooling tower as waste heat from the caustic quench/scrubber. This would require about 600 gpm of cooling water supplied at 30°C and returned at 45°C. A dedicated cooling tower would consume about 10 gpm of makeup water and would produce about 0.5 gpm of blowdown, and need electrical power to serve a 15 HP fan motor. In addition, minor amounts of chemicals (biocides, surfactants, film formers, etc.) would be required for cooling water conditioning.

Mercury Adsorber

The off gas will leave the scrub system at about 50°C and saturated with water. To prevent condensation, the off gas must be reheated to about 70°C before passing through an adsorber containing sulfur-impregnated activated carbon to remove any mercury that might be present. Although no mercury is known to be present, the adsorption bed will be sized to remove about 100 kg of mercury over the two years of operation. Assuming a 10% capacity for mercury on the carbon, the adsorber will contain about 1,000 kg of carbon. The carbon bed will have a residence time of about 3 seconds and a superficial velocity of about 0.3 m/s. The mercury adsorption bed is designed to last the duration of the campaign and will be disposed of as mixed low-level waste upon completion of Pit 9 remediation.

HEPA Filters

HEPA filters, with an efficiency of 99.97% at 0.3 μm , will be used to remove the remaining particulate matter. Roughing and HEPA filters will be replaced as required when pressure drop exceeds specifications. They will then be compacted and, if greater than 100 nCi/g TRU, they will be shipped to the WIPP for disposal.

NO_x Removal

The off gas will then be heated in a recuperative exchanger before a vanadium-based selective catalytic reduction system. A 2 MMBtu/h propane burner will heat the off gas to about 400°C and then ammonia will be injected into the gas stream. The ammonia to NO_x ratio will be about 0.9 to prevent excessive ammonia slip. The SCR will reduce NO_x emissions by greater than 95%. Hot off gas from the SCR will be cooled in the recuperative heat exchanger before being discharged to the atmosphere via the stack. The SCR catalyst should last the entire campaign and will be disposed of as mixed low-level waste upon completion. Ammonia will be supplied from a 1,000 L tank, which will require filling approximately 15 times over the three-year operating period.

Mechanical Uncertainties:

The challenges of operating equipment in an environment of alpha contamination are unique to the nuclear industry. There are few materials as hazardous as plutonium and great efforts are expended to assure that the alpha emitting contamination is confined. Experience with the Process Experimental Pilot Plant (PREPP), a rotary kiln incinerator facility that was built at the INEEL has shown how difficult that confinement can be. The combination of rotating seals, high temperature, and the potential for intermittent overpressure (due to periods of high rates of combustion) make the mechanical design particularly challenging. It should be noted that these problems are not endemic to the rotary kiln. Other types of incinerators have their own set of process and mechanical concerns. Any standard kiln design will have to be modified to adapt it to operation in an alpha environment. Wherever possible, systems that are not in direct contact with the contaminated material will be moved out of the confinement area. For instance, combustion air blowers and the kiln drive motor will be evaluated to minimize the amount of equipment.

The feed and discharge systems must be designed to assure isolation of the contaminated, high temperature environment from the environment. The proposed feed system concept for this study is a series of valves that are operated in sequence to keep the feed hopper isolated from the kiln. This scheme must be further developed to assure that material flow problems and impact of high temperatures (causing the feed to become “sticky”) are identified and addressed. The concept for the discharge system cools the

ash before transferring it to packaging station but again material handling issues such as klinkers, transferred conveyor designs, etc. must be evaluated in prototypes to assure the design solutions are adequate.

The PREPP experience showed that the rotary seals on the kiln are “weak links” in the system. Maintaining the required tolerances over large diameters with substantial changes in temperature is difficult, at best. Again, concepts will have to be tested (in non-radioactive service) early in the design phase to minimize re-work later.

The fact that some of these contaminants are fissile is another major concern. While it may be unlikely, systems must be put in place to assure that fissile material does not accumulate in the system (feed, kiln, or discharge). This control system was not evaluated as part of this study and will have to be addressed in subsequent design efforts.

Maintenance of the kiln in the contaminated environment is also a significant challenge. The refractory lining of the kiln will have to be inspected periodically and eventually replaced, if the Stage III treatment facility is used to remediate other pits and trenches. In a typical incinerator system, this is accomplished “hands-on”. Detailed evaluations of maintenance schemes were beyond the scope of this study but will have to be addressed during the later design phases to assure that the work can be accomplished in an expeditious manner that maintains worker radiation exposure as low as reasonably achievable

Non-TRU Incinerator System Description

The return to pit incinerator system (hereafter referred to as the dirt burner) will provide thermal treatment of pre-conditioned non-TRU mixed wastes from Pit 9 at the INEEL. Major uncertainties remain concerning the rates and composition of the dirt burner feed streams. These uncertainties derive from the fact that both the pit contents and the processes that produce incinerator feeds from the pit contents are, as yet, poorly defined. This process description was based on assumed nominal compositions and rates of the two feed streams to the incinerator. All feed streams to the dirt burner will contain $\leq 100\text{nCi/g TRU}$ and will be derived from two sources:

1. Shredded debris waste ($\sim 60\text{ kg/h}$) containing combustibles, steel, and other non-combustibles
2. Soil and sludge ($\sim 980\text{ kg/h}$) containing Texaco Regal oil and various VOCs, including carbon tetrachloride, trichloroethane, trichloroethylene, and perchloroethylene, with small amounts of ethanol, EDTA, and ascorbic acid.

These streams will be incinerated to reduce the toxicity of waste constituents and to produce a dry, solid ash that is suitable for return to Pit 9. A wide variety of incinerator options could be used to fulfill the primary requirements, including a rotary kiln, single or multiple hearth, stoker grate, batch mass burner, or virtually any other type of fired chamber that will convert the waste materials to off gas and stable solid ash. To support preliminary planning and budgeting, a non-slagging, rotary kiln was selected. Although several manufacturers are available, a design provided by Andersen 2000, Inc. is used as the basis in this description. The incinerator chosen for the dirt burner application is very similar to that chosen for the TRU incinerator.

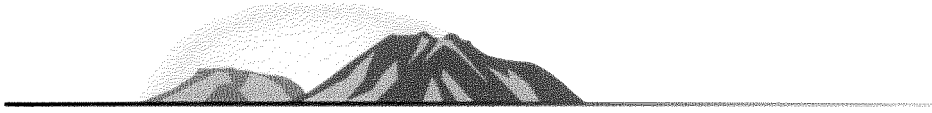
The dirt burner system is comprised of propane-fired primary and secondary combustion chambers, associated feed systems, and an ash removal system. The system is designed to achieve at least 99.99%

destruction of all hazardous organic constituents in the feed. An off gas system will treat the off gas to meet all applicable emission requirements.

While the material processed in this incinerator is not TRU, the design and maintenance issues discussed for the TRU incinerator still apply.

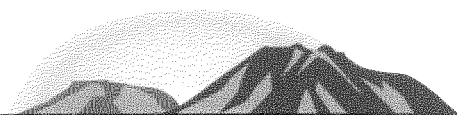
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Appendix E

Process Description for Chemical Extraction



Appendix E

Process Description for Chemical Extraction

Introduction

Pit 9 interstitial and under-burden soils are over 90% by mass of the material in the pit. They are estimated to make up 77% of the volume as retrieved, due to void space introduced by the "fluffing" effect of retrieval. This preponderance of soil significantly reduces the potential for overall volume reduction by conventional processes, because the soil can, at best, only be reduced to 70% of the total volume when it is fully compacted. If melted, the soil carbonate is decomposed, moisture is evaporated, and the mineral residual can be reduced to essentially theoretical density. Combined with the destruction of combustible debris, and melting the mineral and metal residuals from the debris a volume reduction of nearly 50% can be obtained in theory (EDF-3634, "Treatment Technology for OU 7-10, Stage III Project"). However, to reduce the volume any further requires decontamination of the soil to maximize the material that can be returned to the pit, and to concentrate the TRU nuclides in a minimum volume for disposal to the WIPP. Of the many technologies proposed for soil decontamination, chemical leaching was chosen as an alternative for removing TRU contamination from Pit 9 soils because it is the only process shown to have the potential to remove contaminants distributed on the atomic level as opposed to discrete particles.

Nitric acid dissolution is commonly used for recovery of plutonium oxides, but is usually augmented with hydrofluoric acid in laboratory procedures to speed the reaction. This practice is not advisable with a soil matrix due to the prevalence of silica and alumina, as well as corrosion of equipment. Based on the history of the wastes in Pit 9, it is believed that most of the plutonium oxides in the pit come from aqueous precipitation, and ambient temperature oxidation of plutonium metal particles. According to available literature, these oxides should be readily soluble in 6 molar nitric acid at 90°C (Katz, Seaborg and Morss). Using this as a basis, the leach system was designed with a five-hour contact at 90°C with an inlet concentration of 8 molar and outlet concentration of 4 molar nitric acid. Preliminary testing has shown that approximately 25 wt% of the soil matrix is dissolved at these conditions. Oxalic acid precipitation is used to recover the leached actinides and is also well known and currently used in various industries, including fuel reprocessing (Fukunaka et al, 2000, Shin et al, 1996). Waste solutions, including water and neutralized nitrate salts, are evaporated and decomposed in an indirectly fired calciner to minimize the volume of secondary wastes returned to the pit.

Table E-I provides summary values ($\approx \pm 1\%$) of major results from the material balance.

Table E-1. Materials summary.

Inputs, Metric Ton		Outputs, Metric Ton	
soil	6,900	Calcined Solids	8,700
Nitric Acid	14,600	Calcliner Off Gas	6,300
NaOH	8,000	TRU Filter Cake	2,400
Oxalic Acid	16,700	Evaporated Water	24,800
TD Water	2,800	Extractor Off Gas	700
Air	500	Dryer Gas	6,300
Totals	49,500		49,200
TRU (Ci)	7,000	Calcined Solids TRU (Ci)	300
		Filter Cake TRU (Ci)	6,700

Table E-1 shows that 6,900 tons of soil is treated to produce 8,700 tons of solids returned to the pit, a ratio of 1.26 (26% increase). The Table E-1 values for the chemicals used are listed, i.e., 8 M nitric acid, 50 wt% NaOH, and 10 wt% oxalic acid. The caustic and oxalic acid are delivered as a dry material while the nitric acid is delivered and stored in liquid form (13M). The 96% recovery of the TRU components is calculated based on an assumed leaching efficiency of 98%. The process would return the remaining 4% of the actinides to the pit, distributed fairly homogeneously over the 8,700 tons of calcined soil product. Having been heat treated at 700°C, the plutonium residuals are expected to be essentially insoluble under ambient conditions. Actual results may differ significantly and must be determined based on comprehensive testing using actual materials from Pit 9.

Process Description

Leaching Process

Dry soil is received after low-temperature thermal desorption to remove VOCs and is added to the first of three agitated leach vessels. The soil will still be at an elevated temperature from thermal desorption. Pre-heated, 8 molar (8M) nitric acid (HNO_3), is added counter-currently to the third soil leach vessel with the temperature maintained at 90°C using an external steam jacket. The bulk of the dissolution occurs in the first contactor (left in Figure E-1 below). Soil carbonates are dissolved and moist carbon dioxide is vented to the off gas system. After the contact time, the slurry is pumped to a specialized filter (e.g., Fundabac) to separate the residual solids from the liquor. The nitric acid addition is calculated to maintain the filtrate from vessel one at ≥ 4 M. This filtrate leaves the system laden with the TRU to the oxalate precipitation system for TRU recovery. The solids are fed to the second (middle) leach vessel, which also receives the partially spent liquor from vessel three. The chemical leaching and filtration continues in a similar manner in each tank. As the soil solids proceed from one contactor to the next, they are repeatedly leached and rinsed with cleaner acid, resulting in the cleanest soil exiting to the right, where, after filtration the soil is conveyed to a calciner for drying prior to returning to the pit. Fresh nitric acid is fed to the third vessel, dissolving more and more soil and TRU contamination as it progresses to the left in the diagram, exiting after the last filtration to the TRU recovery system. There are three tanks

and the system is operated counter-current as shown in Figure E-I. This design is to minimize chemical use and maximize decontamination.

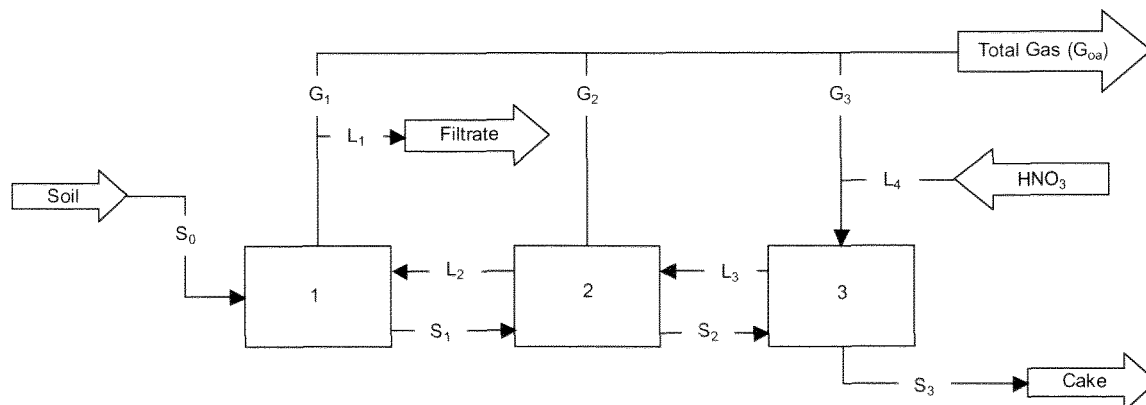
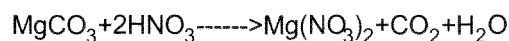
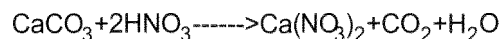


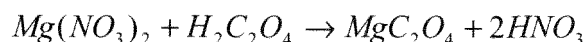
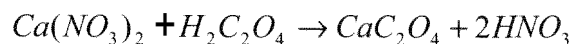
Figure E-1. Leaching process schematic.

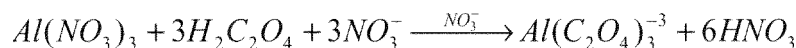
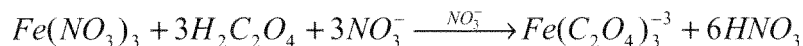
The total reaction time is 5.5 hours, 2.5 hours in the first vessel followed by 1.5 hours each in the second two tanks. The assumed efficiency of leaching is 99% with a nominal filter efficiency of 98%. These values are estimates, which require verification through testing. The acid demand includes actinides, CaCO_3 , and MgCO_3 with the latter two requiring 99+% of the HNO_3 . The inert material (i.e., quartz and feldspar) does not dissolve and constitutes 75 wt% of the soil to be treated. The following equations for the leach chemistry were used.



Precipitation

Actinides are precipitated from the filtrate using oxalic acid. The filtrate acidity must be adjusted to ≤ 0.5 M for the precipitation to be effective. Sodium hydroxide (19M NaOH) is used for this purpose. During the addition of oxalic acid, oxalate complexes are formed and nitric acid is produced, and further NaOH addition is required. Heat of reaction is controlled using cooling water in the tank jacket to maintain the reaction temperature at near ambient. The following chemical reactions occur (actinides not shown) with the first two forming insoluble products, which precipitate.





Based on available test data, reactions require at least 8 hours for 99% efficiency. The oxalate product is fed to a second Fundabec filter, separate from the one used in leachate processing. The oxalate cake produced is the TRU product, which also contains the calcium and magnesium shown above. Note that the aluminum and iron form soluble oxalate complexes that demand oxalate addition, but they remain part of the oxalate filtrate. The TRU product cake is reduced further via incineration prior to transportation to WIPP. The oxalate/nitrate filtrate from this process is neutralized and concentrated by evaporation prior to calcination.

Evaporation

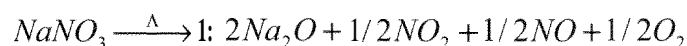
An evaporator is included to reduce the water content of the precipitation filtrate prior to calcination. A 50% (19M) NaOH solution is added prior to the evaporator to neutralize the remaining acid from the precipitation process, which minimizes acid volatility in the evaporator. The steam from the evaporator is filtered and vented. The target solids concentration is less than 30 wt% while not exceeding the solubility limit of NaNO₃ (1.8 g/g H₂O hot), i.e., two constraints are set for slurry transportability and major component solubility.

Calcination

The neutralized evaporator bottoms product (largely NaNO₃ and water) is mixed with the decontaminated soil cake from leaching and fed to a rotary screw calciner. The NaOH added prior to the evaporator above is deliberately added in excess to both minimize any potential acid volatility and neutralize any residual acidity in the soil cake to minimize corrosion in the calciner. The neutralized slurry is dried using a thermal screw at 150°C, and heated to 700°C in the calciner to break down the NaNO₃ via the assumed reactions below:



and/or



There is good reason to assume this reaction occurs with additives similar to those in the INTEC calciner at 700°C based on work at the INTEC calciner system (Nenni, et al, 2000). However, it appears that the sodium could be converted to Na₂O or back to NaOH, which would be expected to flux the silicates in the soil to form sodium silicates. A possible representation is identified in Figure E-2 that shows silicates forming from typical silicates like Kaolin and quartzes found in common soils. Therefore, it is fairly certain that the NaNO₃ will break down but the assumed reaction above may not be comprehensive and should only be assumed for the purposes of estimating heat loads and ultimate masses for return to the pit.

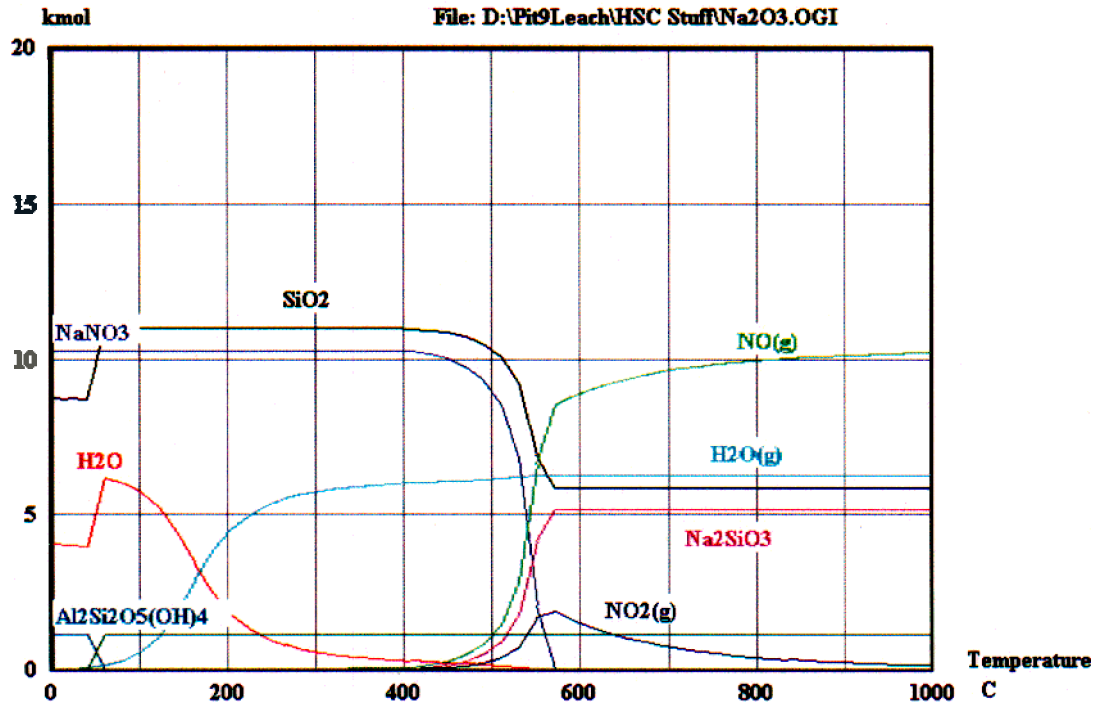


Figure E-2, Probable calciner reactions.

Off Gas

The calciner off gas system is designed primarily to destroy NO_x produced in the calciner. In addition, a small amount of particulate matter carryover will be removed to prevent slugging in the NO_x abatement system. Below is a description of the calciner off gas system.

Off gas from the calciner will first be passed through a refractory-lined hot cyclone designed to remove 90% of the incoming particulate matter (PM) greater than 40 μm . The cyclone will operate at 315°C. The off gas flow rate will be about 26 Am^3/min , with a particulate loading of about 0.5 kg/min. The size of the hot cyclone would be about 2 ft in diameter and 5 ft tall, not including associated piping.

From the exit of the cyclone, the offgas will pass through a water-cooled heat exchanger to reduce the temperature to about 170°C before entering a hot baghouse filter about 90% of the remaining PM. The off gas flow rate will be 26 m^3/min , with a particulate loading of about 0.05 kg/min. Particulate matter from the cyclone and the baghouse will be returned to the calciner to be combined with the clean soil that is returned to Pit 9. The size of a typical baghouse type filter would be about 6 ft wide by 6 ft deep by 6 ft high. In addition, a minimum of about 6 to 8 feet would be required beneath the filter to allow removal of ash into a drum.

The principal component of the calciner off gas system is a multi-stage oxidizer. Information from John Zink Company regarding their No_xidizer[®] system was used in this description. The inlet flow rate of 26 Am^3/min will contain a total NO_x concentration of about 15%. Total destruction removal efficiency (DRE) must be at least 99%. In the first section, a propane-fired burner will operate with sub-stoichiometric air to produce high-temperature, reducing conditions, which will reduce NO and NO₂

to N_2 . The temperature in the reducing section will be $1,200^{\circ}C$. Following this section, about 200 kg/h of water will be injected to quench the off gas to about $1,000^{\circ}C$. The off gas then passes through the re-oxidation section, where additional air is injected to oxidize CO and unburned hydrocarbons produced in the reducing section. Water is injected into the re-oxidation section to maintain the temperature at a maximum of $1,000^{\circ}C$, at which temperature reformation of NOx is minimized.

At the exit of the multi-stage oxidizer, a partial quench will reduce the temperature to about $120^{\circ}C$ but maintain the relative humidity low enough to prevent condensation in the HEPA filters. Overall length of the multi-stage oxidizer is about 40 ft, with a diameter of 6 ft. It would be possible to “fold” the unit after the reducing section to reduce its overall length to about 20 ft. The width would remain the same at 6 ft, but the height would increase from 6 ft to about 14 ft.

Following the quench, the off gas is combined with off gas from the leach evaporator and from the thermal desorption condenser overhead. The off gas is passed through HEPA filters, combined with the “clean” incinerator off gas, and sent to the stack for release.

Assumptions

- Several densities were assumed. This led to minor errors in the material balances.
- The leaching/dissolution is 99% efficiency at $90^{\circ}C$ and 5.5 hours residence time
- TRU will dissolve in the hot, 4+M nitric acid. (Insignificant refractory plutonium)
- Target TRU value for the calciner product is $TRU < 100 \text{ nCi/g}$
- The soil contains 75% material that is inert to nitric acid and does not dissolve
- The porosity of all solid matrices is $\epsilon = 0.4$
- The soil density (dry) is 1.5 kg/L
- The oxalate precipitation step is 99% efficient at ambient conditions and 8 hours residence time
- Solid handling and transport by slurry requires that the solids are less than 30 wt%
- The cake from leaching/dissolution and oxalate precipitation is 100% saturated with liquid
- The cake from the leaching/dissolution contains liquid of the same nitric acid concentration as the incoming acid, i.e., 8M
- For the design of the leaching/dissolution process, the exiting filtrate concentration from a stage equals the exiting cake pore liquid
- TRU contamination consists of an average Am and Pu activity ratio of $Am/Pu = 2$
- The thermal break down of $NaNO_3$ is as shown at $700^{\circ}C$
- The dry, desorbed soil may contain some heavy oils. The effect of oils was not accounted for.

Uncertainties

Some forms of TRU (fired at high temperatures) will not readily dissolve in nitric acid. If some of this material is present in the soil, it is assumed to be present in the cake from extraction/dissolution and ends up in the calciner solids product where it will be assayed. It is assumed that the prevalence of this

refractory plutonium is not significant and the leached materials will generally not exceed the criteria for return to Pit 9. However, it is possible that this material or leach products from batches that contain unusually high levels of actinides could pass through the system and exceed criteria. The batches from both of these potentialities would be sent to WIPP. No estimate can be made without greater pit characterization, but it is assumed that the volume of this material is insignificant.

As discussed above, there is uncertainty in the calcination of NaNO_3 as shown. For the purposes of this preliminary design effort, the first reaction was used. However, further work is needed to address the soil composition and use it to determine the silica products expected. Further simulation may lead to a PFD with lower calciner temperatures and a lower energy decomposition of nitrates with a better design basis.

References

Fukunaka, Y., Kuzuya, T., Niinae, M., Kusaka, E., Ishii, R., "Precipitation Stripping of Samarium Oxalate Particles," *Proceedings of Second International Conference on Processing Materials for Properties*, pp. 949-954, November, 2000, 00BRE10203.

HSC Chemistry for Windows, Outokumpu Research, Oy, Finland, 2002.

Katz, J. J., Seaborg, G. T., and Morss, L. R., Chemistry of the Actinide Elements, 2nd Ed., Vol 1., Chapman and Hall, London and New York, 1986.

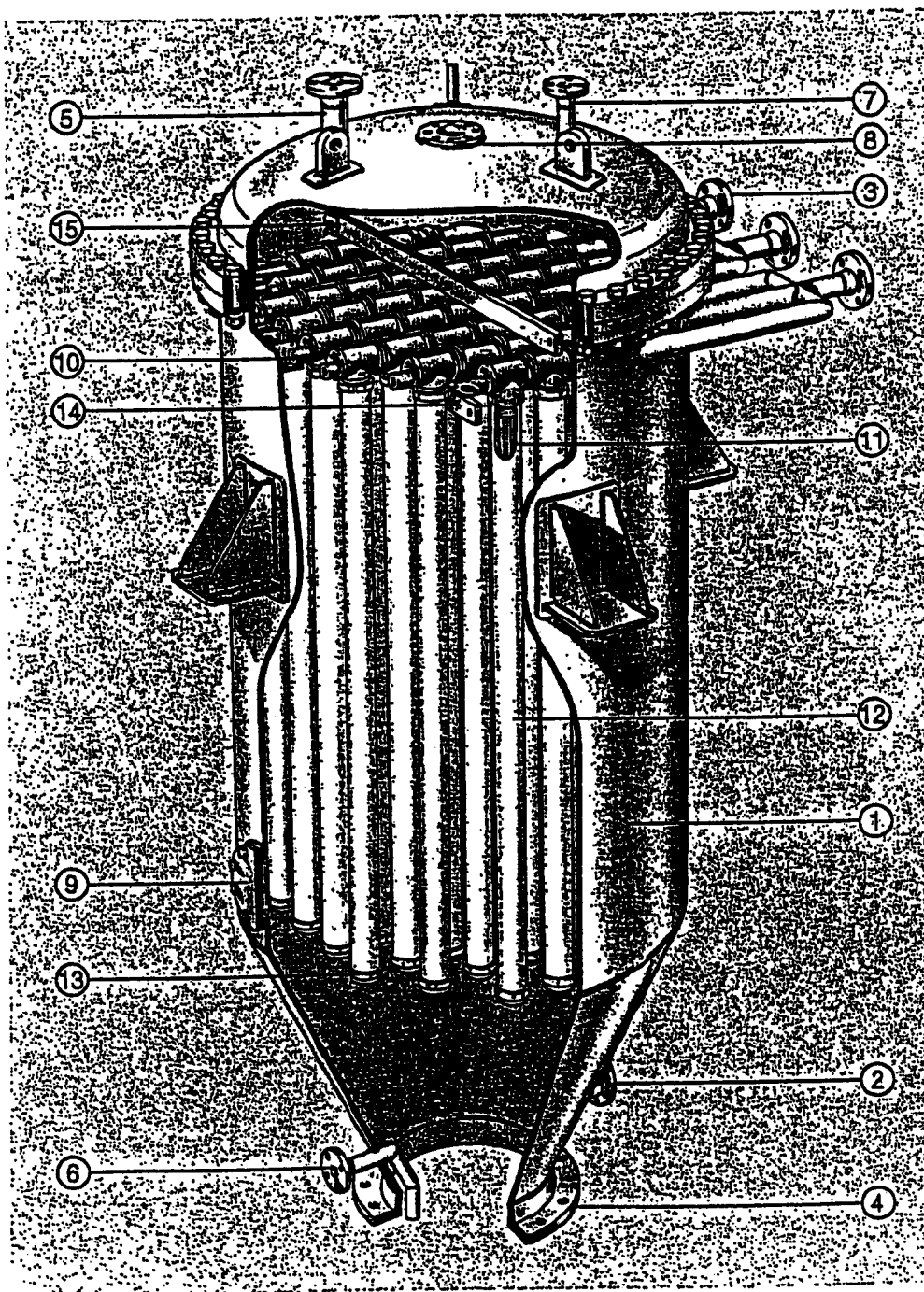
Nenni, J. A., O'Brien, B. H., Schindler, R. E., Wood, R. A., *NWCF Off Gas Line Restriction Identification and Resolution*, INEEL/EXT-2000-00322, INEEL, March 2000.

Ramer, R. J., Treatment Technology Screening for OU 7-10 Stage III Project, EDF-3634, June 26, 2003

Shin, Y. J., Kim, I. S., Lee, W. K., Shin, H. S., Ro, S. G., "Precipitation Behavior of Uranium in Multicomponent Solution by Oxalic Acid", *Journal of Radioanalytical and Nuclear Chemistry*.

Vol: 209, Issue: I, September, 1996.

FUNDABAC® Filter for dry and slurry discharge Type R



- 1 Pressure vessel
- 2 Product feed nozzle
- 3 Filtrate nozzles
- 4 Solid-residue discharge nozzle
- 5 Overflow and vent nozzle
- 6 Heel volume nozzle
- 7 Instrumentation nozzle
- 8 Saddle flange for heel filtration spray jet nozzle
- 9 Inspection port
- 10 Register
- 11 Filter element
- 12 Filter medium (cloth, felt, membrane etc.)
- 13 Cloth clamp ring
- 14 tower register support bar (only for synthetic internals)
- 15 Upper register support bar. (only for synthetic internals)

Fig. 1
Discharge system consisting of two 22 FUNDABAC® Filters in a steel plant

Fig. 2
Schematic of Heel Volume Filtration

Fig. 3
Two FUNDABAC® Filters R-16 m² for the production of Acrylonitrile in a petrochemical plant Downward view of the filtrate outlet valves

FUNDABAC® filter system? Four functions in one unit.

1. Filtration and heel volume filtration (Pat.)

The uniform and random distribution of solids throughout the liquid in the filter is achieved by creating an upward flow by means of a controllable overflow. This ensures an even build-up of cake on the filter elements.

If at the end of the filtration the unfiltered heel cannot be drained to the feed vessel, a heel volume filtration must be carried out. This is achieved by the patented heel filtration as follows: from the lowest point in the vessel the heel is sucked by the filter pump and returned to the vessel through the centrally located spray nozzle in the cover. There, the sprayed heel is evenly distributed on the filter elements and the liquid pushed through the cake by gas pressure (fig. 2).

2 Cake washing

At the end of the filtration step, resp. heel filtration stop, or draining of the filter by gas displacement, the cake can be subjected to the washing step by a suitable wash-phase. The sprayed wash-phase using the heel filtration method significantly reduces the volume of the wash liquid compared to conventional washing (fig. 2).

3. Cake drying

The washed cake is dried by blowing a suitable gas phase, e.g. ambient or hot air, nitrogen or steam through the cake on the filter elements, until the required level of residual moisture has been reached.

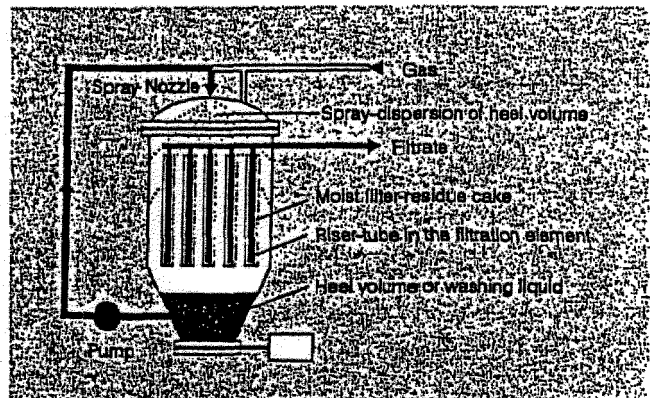
The cake remains on the filter medium during the entire process due to the unique geometric arrangement of the tubes in the filter elements. At the end of the drying cycle the pressure vessel is vented and the discharge device opened to discharge the solids.

4. In-situ cleaning of the filter hoses

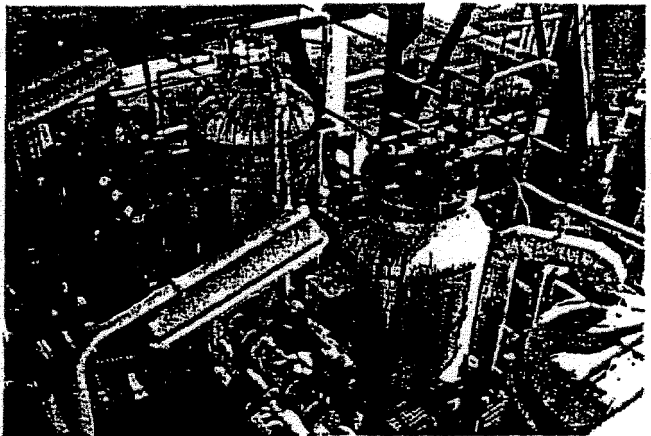
In-situ cleaning assures longer life of the filter media. As programmed according to need, the filter media are automatically washed in the closed filter to free them from possibly strongly adhering particles.



1



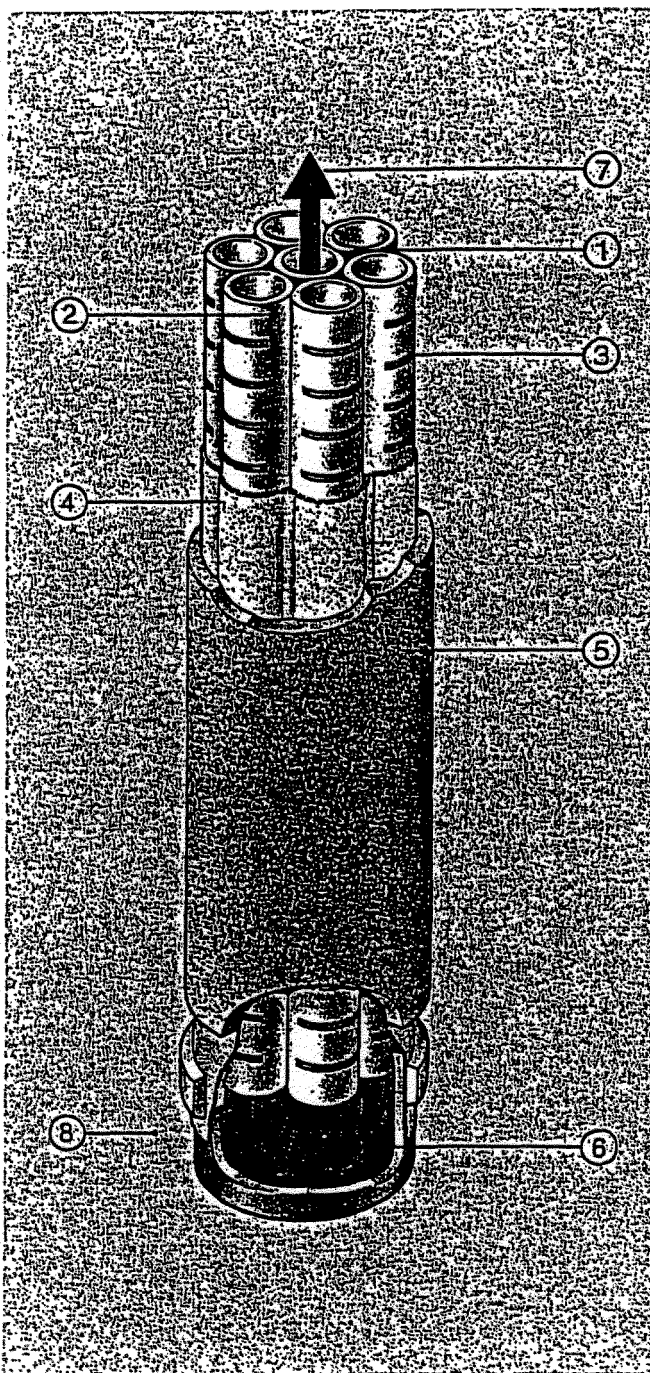
2



3

Filter elements – heart of the filter

The formation of the cake and the course of drying



Solids

During the filtration, which takes place in a pressure vessel, the liquid is pressed from the outside through the filter medium. Solids collect on its surface and form a uniform cake. The cake remains on the filter elements due to their concave-convex profile and a continually maintained pressure differential across them.

Filtrate

The filtrate flows downward through the six concentric filter tubes, rises inside the central tube and leaves the filter via the registers mounted in the upper portion of the pressure vessel.

Cake drying

During the pumping out of the heel volume from the filter vessel and the drying phase, gas is forced through the filter cake in the direction of the filtration towards the inside of the filter element. At the same time, the central tube guarantees that the cake on the filter element is de-watered and that the remaining liquid in the filter element is displaced by the gas without any trace of liquid remaining.

1 Central tube

Filtrate collector with solid wall for total displacement of filtrate from the filter element

2 Filter tube

Support for filter medium, tube-bundle with apertured walls.

3 Typical apertures and filter tubes

4 Filter medium

Pressed against the bundled filter tubes during filtration

5 Filter cake

6 Collection chamber

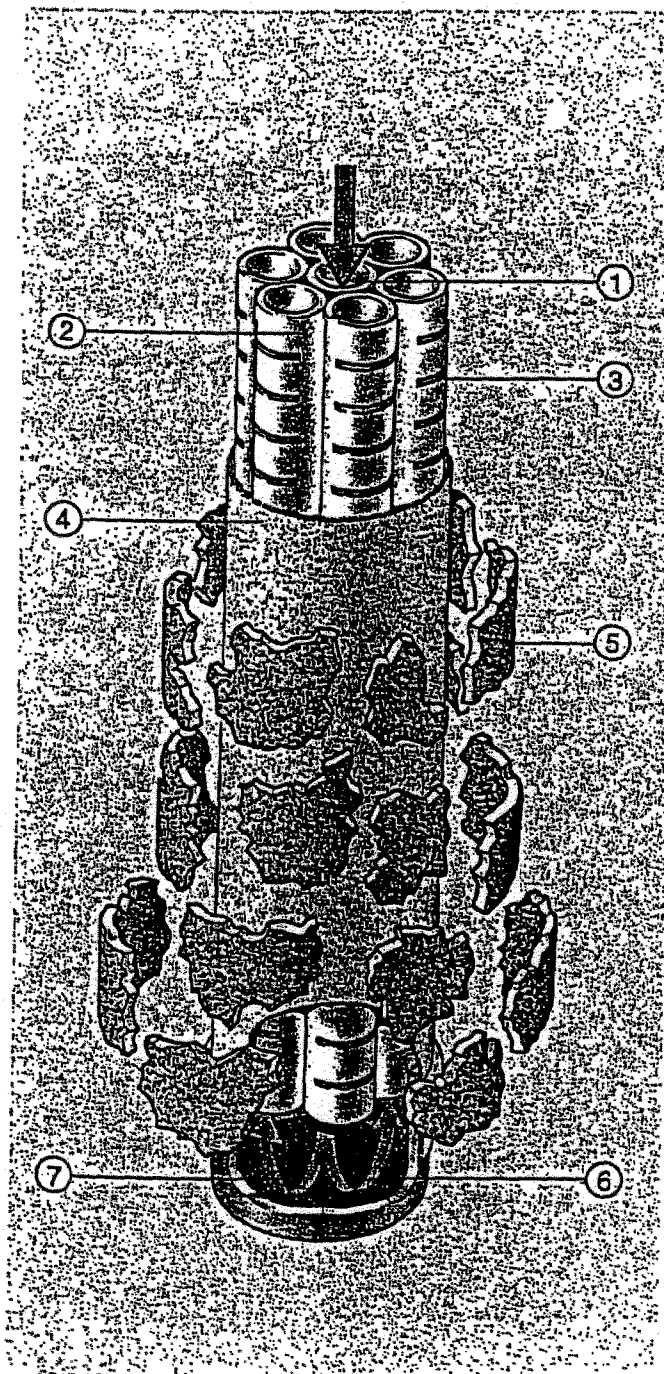
Connecting central tube (1) with filter tubes (2)

7 Filtrate

Exits filter element through central tube

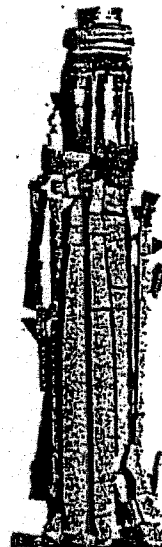
8 Unfiltered suspension

Dry discharge of filter cake



FUNDABAC®

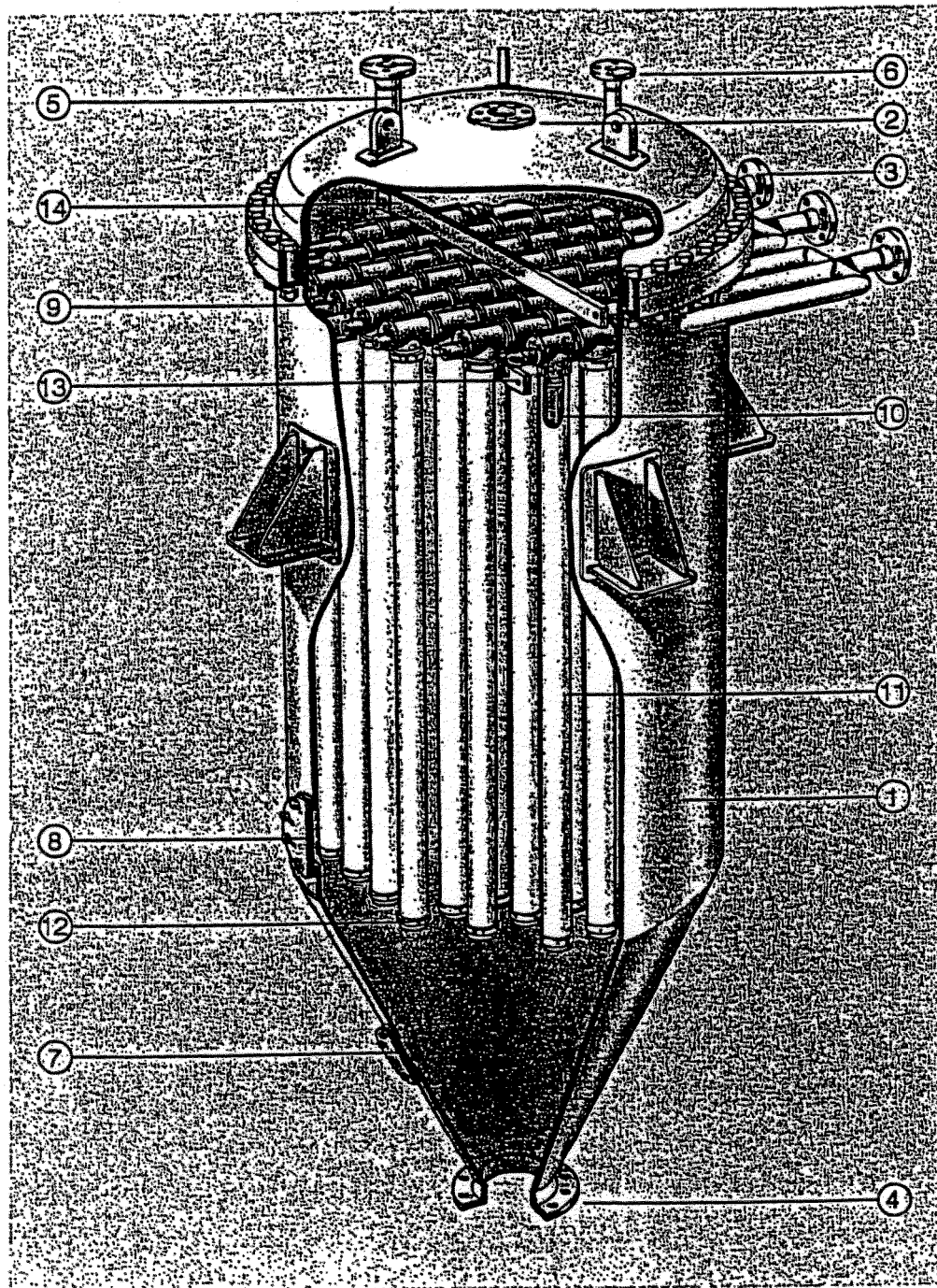
After emptying the filter vessel, cake washing and drying, each filter element is subjected to a reverse gas flow pressure shock. As the filter medium expands, vertical cracks are generated in the cake. When the medium reaches its maximum deflection, its movement stops and the cake is thrown off. Filter cakes of 3 to 50 mm thickness are completely discharged.



Stroboscopic photograph of cake discharge

- 1 Central tube**
Blow-back entry line
- 2 Filter tube**
Distribution of blow-back gas
- 3 Typical apertures on filter tubes, for blow-back gas**
- 4 Filter medium**
Convex / concave clover-leaf profile suddenly becomes round
- 5 Filter cake**
Range of cake-thicknesses 3 to 50 mm
- 6 Collection chamber**
Connecting central tube (1) with filter tubes (2)
- 7 Blow-back gas**
Initiates the discharge of the filter cake.

CONTIBAC®-Filter Thickener for continuous thickening Type RC



- 1 Pressure vessel
- 2 Slurry feed nozzle
- 3 Filtrate nozzles
- 4 Thickened sludge discharge nozzle
- 5 Vent nozzle
- 6 Instrumentation nozzle
- 7 Probe for sludge detector
- 8 Inspection port
- 9 Register
- 10 Filter element
- 11 Filter medium
- 12 Cloth clamp ring
- 13 Lower register support bar (only for synthetic internals)
- 14 Upper register support bar (only for synthetic internals)

By slightly modifying the FUNDABAC® Filter it can be operated as a continuous thickener, known as the CONTIBAC® System.

Unlike conventional thickeners the CONTIBAC® creates a clear supernatant filtrate.

Clear filtrate as well as high throughput

A clear filtrate is obtained by the use of finely woven media, felts or membranes of fine porosity. For difficult to filter product-streams short filtration cycles build up very thin cakes, which keep the rate-of-filtration always at the high initial flux-rate.

Filtration Cycle

Filtration starts after a very brief pre-filtration step. Product stream feed ceases and thus the filtration. The formed cake is displaced from the filter medium into the filled filter by a pulsing blow-back. This action is performed register-by-register group. The freed filter cake remains compact and sediments rapidly, settling

in the conical bottom of the filter.

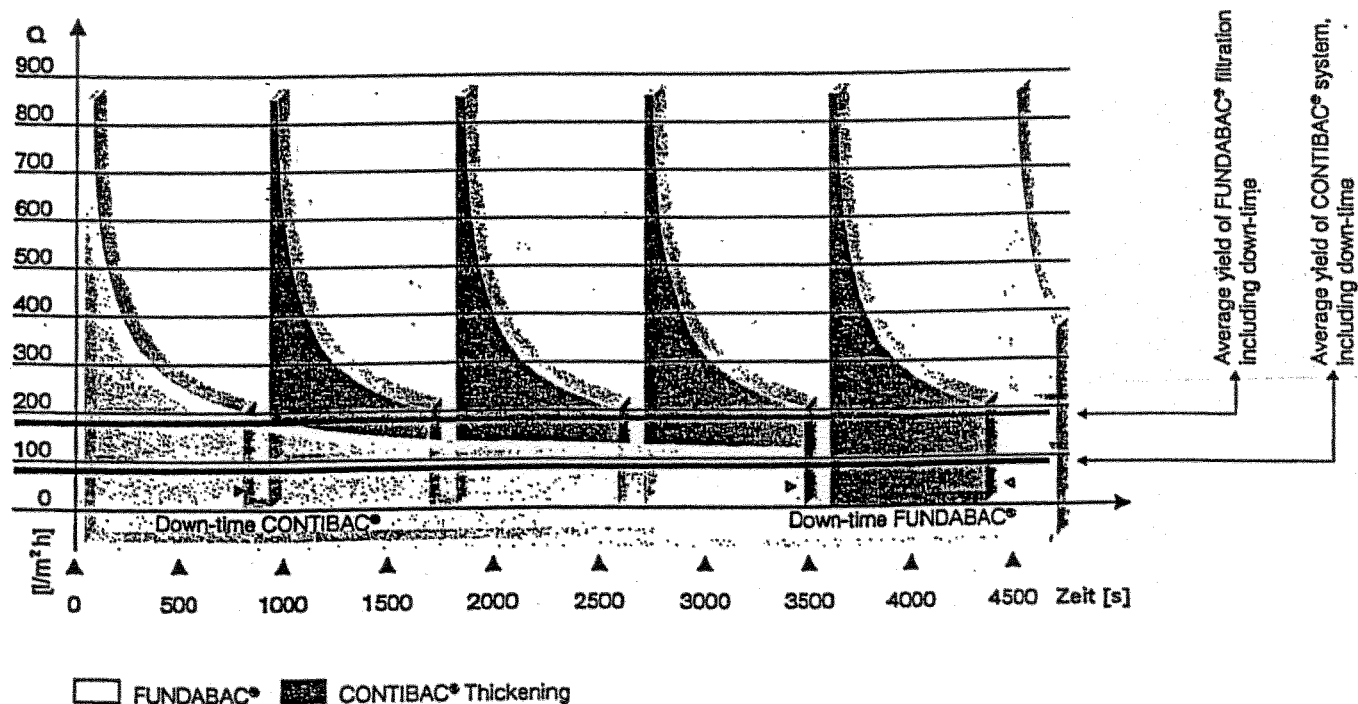
The next filtration cycle starts immediately. Actual down time lasts only a few minutes.

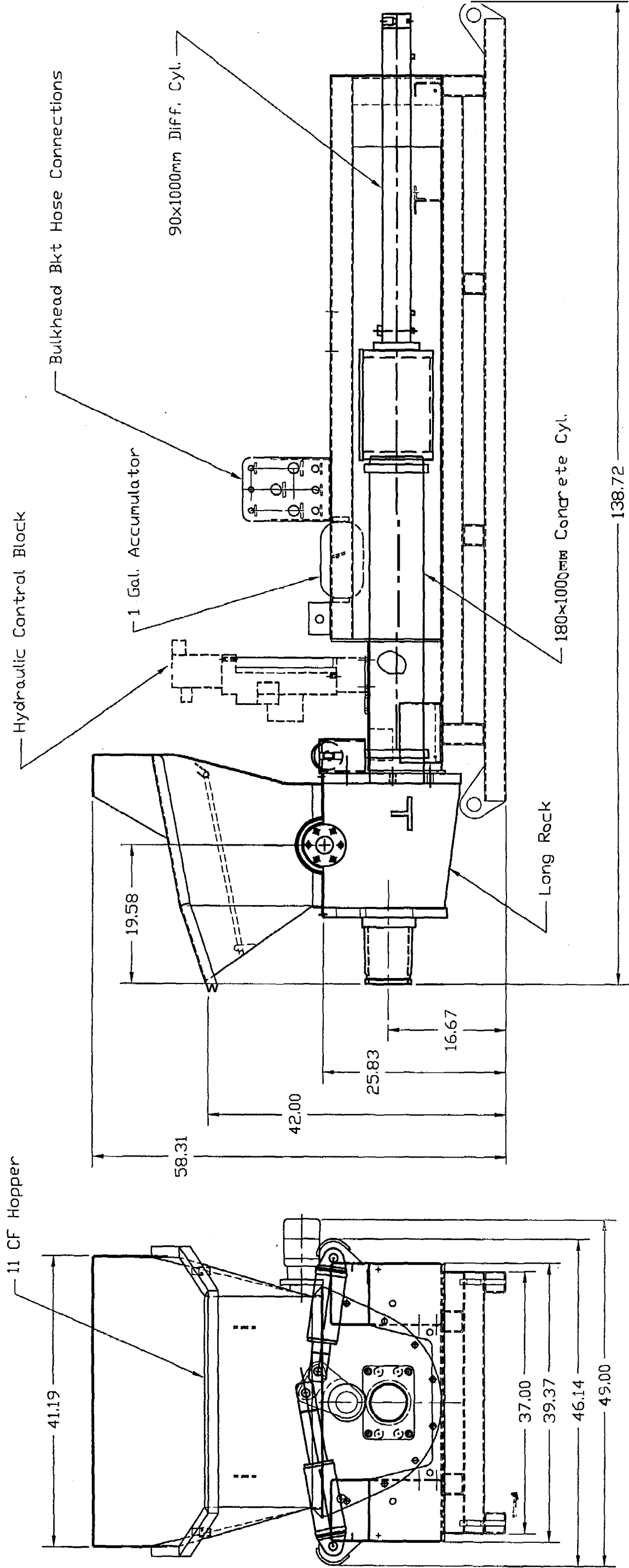
Discharge of the concentrated suspension


The concentrated sludge is discharged during the next filtration cycle; the cycle is NOT interrupted by this discharge.

The discharge is affected through the bottom opening of the filter, by means of a sluice or similar device.

Example from actual process conditions:
Difference in yields, between FUNDABAC®
Filtration and CONTIBAC® Thickening







WHITE BEAR, MN 55127
Subsidiary of
F.W.SCHWING GmbH

DATE

09-28-99

DRAWN BY

eg

APPROVED BY

eg

SHEET

1

ASSEMBLY NO

R

DWG NO

30394004

1 OF 1

DID NOT SCALE DRAWING

BREAK ALL SHARP CORNERS

UNLESS OTHERWISE SPECIFIED

TOLERANCE:

WELDMENTS ± 1/8

HOLES +.008

- .000

XXX ±.005

XX ±.040

X ±.080

PUMP CELL

KSP 25 H(K)R